THE EFFECT AND AFTER-EFFECT OF VARIED EXPOSURE TO LIGHT ON CHICKEN DEVELOPMENT

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The basic factor necessary for initiating development of the gonads of birds, according to Rowan (1938), appears to be length of day. Intensity above a certain low threshold, he says, appears to be of no significance. Frequency of light stimulation plays an important role according to Benoit (1936) and, more recently, Staffe (1951), Kirkpatrick and Leopold (1952), and Farner *et al.* (1953a). On the other hand, with uninterrupted lighting early growth was delayed and reproductive performance adversely affected, as shown by studies of Lamoreux (1943), Callenbach *et al.* (1944), and Ringrose and Potter (1953).

Since most of the studies cited above involved wild birds, it remains to be seen whether their results are directly applicable to the domestic fowl; this is particularly true for strains of chickens that have been bred for egg production. Previous work on the effect of intermittent lighting on laying hens by Wilson and Abplanalp (1956) has indicated that egg production can be maintained with very small amounts of light energy, provided it is given intermittently (less than six one-minute intervals in 24 hours). These results tend to support earlier findings by Staffe (1951), who demonstrated that short light flashes from 1500-watt lamps were effective in stimulating laying hens to increase winter egg production.

The present study was conducted in order to gain further information about the effects of intermittent lighting upon the development of chickens. It was, however, restricted to an investigation of early growth and the onset of sexual maturity in pullets.

Material and Methods

Two experiments were conducted with Single Comb White Leghorn stock of the University of California at Davis. In the first, pedigreed chicks were hatched on December 4, 1953. The purpose of the test was to study the effect of supplementary light on the development of chickens. Each hen's chicks were distributed as equally as possible among six experimental groups. Each lot of chicks was then brooded and reared in 15 × 15-foot pens of a house with open fronts. Natural light was given to all six pens, but three received supplementary artificial light from a continuously burning 100-watt incandescent bulb. Three brooding methods were used with the two light treatments as follows:

Group	Brooder type	Light regime
1	4 infrared lamps	Natural light only
2	Electric	Natural light only
3	Gas	Natural light only
4	4 infrared lamps	Natural light + 100 W continuous
5	Electric	Natural light + 100 W continuous
6	Gas	Natural light + 100 W continuous

The gas brooders provided a somewhat higher room temperature than either of the other types.

Brooding was discontinued when the chicks were 6 weeks old. A week later, at 7 weeks of age, the chicks were scored for feathering. Four grades were used in assessing completeness of feathering, ranging from 1 for poorest feathering to 4 for best performance. Both sexes were scored.

At the same time a few males from large families were killed in order to determine comb and testis weights. Body weight was measured first at 7 weeks of age and from then on at 4-week intervals. Age at first egg and the average weight of the first three eggs were determined whenever possible.

The second experiment was to determine effects of intensity and frequency of lighting upon growth and sexual development of pullets. Pullet chicks were hatched on July 1, 1955, and all brooded alike up to 5 weeks of age. The following brooding and lighting regime was used:

0–1 weeks of age: 10-watt bulb; continuous light
1–3 weeks of age: 40-watt bulb; continuous light
3–5 weeks of age: 10-watt bulb; continuous light

Shielded incandescent light bulbs were the only source of heat.

At 5 weeks of age, and in some cases again at 90 days of age, the experimental lots of birds were subjected to changes in lighting regime, according to the following plan:

Group	Light intensity (foot-candles)		Total hrs. light in 24 lours	Number of light periods in 24 hours after 90 days of age
	35–90 days	After 90 days		
A	0.5–30.0	0.5–30.0	14.0	1
B	0.0–0.4	0.5–30.0	14.0	1
C	0.0–0.4	0.0–0.4	1.5	12; 6; 3; 2.
D	0.5–30.0	0.0–0.4	1.5	12; 6; 3; 2.
E	0.5–30.0	0.4–6.6	1.5	12; 6; 3; 2.

As indicated in the table above, groups C, D, and E were each divided into four subgroups at 90 days of age, and the latter were subjected to light periods of varying frequency, while the total duration of lighting was held constant. The 12 light periods per 24 hours consisted of 7.5 minutes each, followed by 52.5 minutes of darkness. Similar regularly spaced periods of light were used where six and three stimuli were given. In the case of two light periods, however, 45 minutes of light was alternately followed by 7 hours, 15 minutes and by 15 hours, 15 minutes of darkness. Group A served as control and was held under "cool white" fluorescent lighting with 14 hours of light per day. Light intensities varied between 0.5 and 30.0 foot-candles according to the location of individual laying cages.

Four windowless climatic chambers were used for this experiment; they have been described in detail by Wilson and Abplanalp (1956). Each chamber was subdivided into two sections with a partition of black sisalkraft, in order to allow replication of treatments. Thus, each lighting regime was given in two different chambers. A diagrammatic outline of this arrangement is given in Figure 1.

Temperatures were held constantly at approximately 80° F. The pullets were

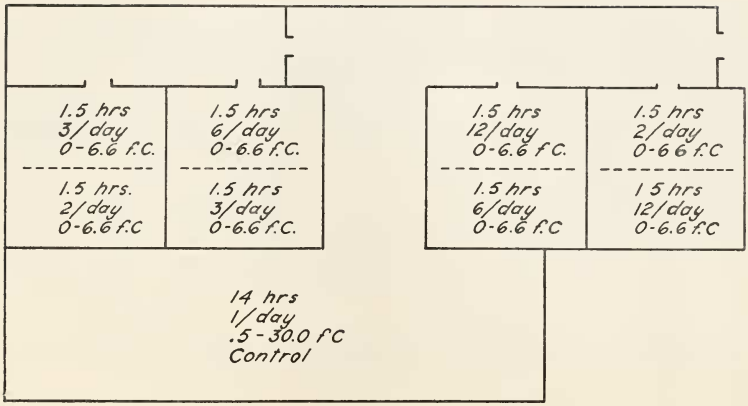

FIGURE 1. Floor plan of experimental rooms showing location of replications. Total light per day, number of light periods per 24 hours, and intensity in foot-candles are given in order for each subgroup.

placed in individual 10-inch cages when they were 5 weeks old. Two double rows of cages were arranged in step fashion, which meant that the birds in the upper rows were somewhat closer to the light source than those in the lower cages. The top rows were 18 inches from the light source, while the bottom ones were 3 feet distant. Light intensities varied between 0.0 and 0.4 foot-candles for the lower tiers and between 0.4 and 6.6 foot-candles for the upper ones.

Experimental lighting was held at suboptimal intensities in order to bring out more clearly the possible effects of frequency of light periods.

The following traits were observed and analyzed: 1) Body weights at 12, 20, and 28 weeks of age; 2) age at first egg for individual pullets; and 3) average

TABLE I

Effect of supplementary light on growth, feathering and sexual development of December-hatched chicks.
Number of individuals in parenthesis

C–22	Body weight, females gms.				Testes wt. at 7 weeks (gms.)	Feather score	Aver. age at 1st egg (days)	Aver. wt. 1st 3 eggs (gms.)
	7 wk.	12 wk.	16 wk.	20 wk.				
No artificial lights	(189) 436	(189) 1023	(189) 1322	(189) 1605	(36) .240	(553) 3.47	(189) 157.7	41.0
100-watt lights cont.	(190) 452	(190) 1006	(190) 1303	(190) 1519	(32) .284	(545) 3.21	(190) 163.8	43.6
Difference	−16*	17	19	86**	−.044**	.26**	−6.1*	−2.6**

* = $P < .05$.
** = $P < .01$.

TABLE II

Relation of light intensity at different stages of growth and age at first egg. Group A and B received 14 hours of light after 90 days of age, other groups 1½ hours

Group	No.	Light treatment foot-candles		Body weight (gms.)			Median age at 1st egg (days)	Aver. wt. 1st 3 eggs (gms.)	At 248 days % maturity
		Between 35–90 days	After 90 days	12 wk.	20 wk.	28 wk.			
A	10	0.5–30.	0.5–30.	1031.	1514.	1744.	153.	39.7	100
B	10	0–0.4	0.5–30.	990.	1505.	1779.	161.	42.2	100
C	40	0–0.4	0–0.4	1017.	1391.	1707.	191.	48.9	85
D	40	0.5–30.	0–0.4	1013.	1466.	1838.	179.	47.5	72
E	40	0.5–30.	0.4–6.6	958.	1426.	1705.	169.	45.1	95

weight of first three eggs laid (whenever possible). Median age at first egg was used as a measure of sexual maturity of entire groups of pullets.

RESULTS

The results of the first test are shown in Table I. Continuous light added to natural illumination apparently favors early growth of chicks up to at least 7 weeks of age. Later on, and most conspicuously at 20 weeks of age, the effects of continuous light supplement are just the opposite. Significantly higher body weights were found at 20 weeks for the birds brooded under natural light only.

Comb weight of 7-week-old males shows little or no effect as the result of different light treatments, but testis weights responded in the same way as body weight. Added continuous lighting resulted in significantly heavier testes at 7 weeks of age.

Continuous light tends to retard feathering and sexual maturity of pullets (but not of males). The 6-day differences in maturity between supplemented and control groups was highly significant. This delay in age at first egg was associated with a somewhat higher weight of first eggs.

The results of the second experiment are given in Tables II and III. In Table II the data are arranged according to total amount of daily lighting and light intensities. Table III, on the other hand, shows the effects of increasing frequencies of light periods with a given amount of light applied after 90 days of age.

TABLE III

Frequency of light intervals/24 hrs. in relation to growth and age at first egg

Light foot-candles	Light periods/24 hrs.		Total light/24 hrs.	No.	Aver. body weight (gms.)			Median age at 1st egg (days)	Aver. wt. 1st 3 eggs (gms.)
	Number	Length			12 wk.	20 wk.	28 wk.		
0–6.6	12	7½ min.	90 min.	30	991.	1437.	1751.	168.0	46.5
0–6.6	6	15 min.	90 min.	30	980.	1410.	1736.	174.0	46.1
0–6.6	3	30 min.	90 min.	30	1011.	1481.	1826.	190.5	48.0
0–6.6	2	45 min.	90 min.	30	1002.	1381.	1750.	189.0	47.6
0.5–30.	1	14 hrs.	14 hrs.	20	1010.	1510.	1759.	160.0	41.2

The observed body weights of pullets do not show any clear-cut effects of either light intensity, amount of light, or lighting frequency.

Sexual maturity as measured by median age at first egg, however, was strongly affected by differences in lighting, both before and after 90 days of age. The control treatment (group A) with highest light intensity during early and late periods of development matured earliest. Group B, with low light intensity to 90 days of age but high intensity thereafter, matured 8 days later. Similarly, groups E, D, and C show consistently adverse effects of reduced light intensities upon age at first egg.

The influence of light intensity on maturity is apparently operative over a considerable period of early development and is not merely restricted to a period very close to the onset of egg production. This can best be shown by regrouping the results of median age at sexual maturity.

Light before 90 days of age	Light after 90 days of age		
	Dim	Bright	Difference
Dim	191	161	30
Bright	179	153	26
Difference	12	8	—

Here it may be noted that bright light administered before pullets were 90 days old advanced sexual maturity by only 12 and 8 days, while intensive lighting after 90 days of age produced effects of 30 and 26 days. This clearly indicates that the influence of light intensity upon sexual maturity becomes more pronounced the closer toward onset of lay it can operate.

Table III shows the effects of more frequent light periods on age at first egg. In each case the birds received a total of 90 minutes of dim light in 24 hours. The results are clear-cut and show that light is more effective in stimulating sexual development the more frequently it is applied. Thus, 12 short periods of dim light permitted pullets to mature almost as early as one 14-hour period of intensive light. The same amount of dim light given in only two doses, on the other hand, resulted in extremely late maturity. These findings are shown more clearly in Figure 2. The data represent medians for the replicate lots. Each lot contained subgroups which differed in light intensity. See regime for groups C, D and E.

Discussion

The first experiment confirmed that growth of the domestic fowl can be influenced by light. All-night lights may have aided early growth in this experiment by providing the chicks more opportunity to feed. Frequent feedings may be particularly helpful when the crop capacity of chicks is still poorly developed.

The adverse effects of continuous lighting after 7 weeks of age, as found in this study, are in agreement with findings by Tomhave (1954).

The results of the second test with respect to growth after 12 weeks of age are not conclusive. They fail to substantiate reports by Clegg and Sanford (1951) and by Barott and Pringle (1951), who found that intermittent lighting has a beneficial effect on early growth of chickens prior to 12 weeks.

In this study it has been found that continuous light has adverse effects on feathering, becoming more serious as the birds become older. Similar effects of continuous light on turkeys have been reported by Mueller *et al.*, 1951.

The role of continuous light in the sexual development of chicks appears to be a complex one. While the 7-week-old cockerels showed increased testes weight under continuous lighting, the pullets appeared to be delayed in their development. Unfortunately, there were no testes measurements available for cockerels near maturity; hence, it is difficult to assess the possible importance of refractory behavior of pullets. Evidence of retarded growth at 20 weeks of age indicates, however, that both cockerels and pullets may have been delayed sexually near the point of maturity.

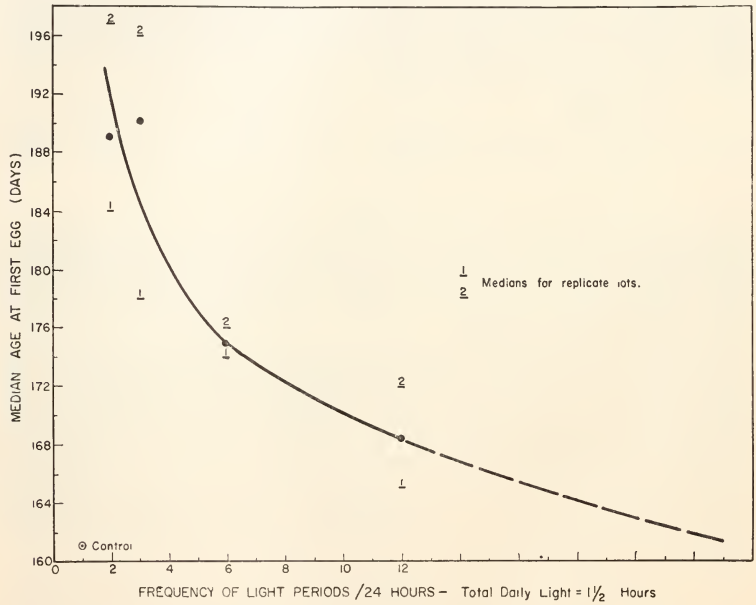

FIGURE 2. The relation of frequency of light periods and age at first egg.

From the results of the second experiment, as well as from an earlier report by Wilson and Abplanalp (1956), it is clear that the total amount of light is not the sole determinant in stimulating sexual development of pullets. Aside from the adverse effects of continuous lighting (which may possibly be due to a nervous fatigue of the animal), it has also been demonstrated here that light intensity and the distribution and frequency of light stimuli are important variables that must be considered in the problem of light stimulation.

The present results show that under limiting conditions of low light intensities and short periods of light exposure, the rate of sexual development increases with longer total daily exposure to light, greater light intensity, and more frequent stimulation. These relationships may not hold when either light intensity or total duration of light exposure is increased beyond certain thresholds. Nevertheless, they

permit certain conclusions of practical value. Thus, where natural light is to be supplemented, it would seem reasonable to use frequent but short intervals of artificial lighting in place of continuous lighting or of light periods adjoining the natural day.

Several attempts have been made recently to rationalize the response of birds to light. Wolfson (1953) interprets his data as supporting the hypothesis that the total daily dose of light determines the response. He postulates, however, that the proportion of light exposure to darkness in a given cycle is the critical factor in determining the response rather than the daily dose of light.

Kirkpatrick and Leopold (1952), in agreement with Jenner and Engels (1952), maintain that the dark period *per se* is a major controlling factor in the response of birds to light. Such an interpretation appears primarily different in terminology and emphasis but seems to add little to an understanding of the problem. It has been criticized by Hammond (1953) and by Farner *et al.* (1953b).

In the light of this study, the theory advanced by Farner *et al.* (1953b) seems the simplest and most suitable for explaining the action of light in reproduction of birds. In brief, it postulates that there exists a light-sensitive gonadotropic mechanism capable of activation almost immediately upon onset of lighting; it remains active throughout the light period and even for some time following termination of the latter. This theory has helped to explain the effectiveness of extremely short photoperiods (a total of 6 minutes in 24 hours) in maintaining egg production of chickens (Wilson and Abplanalp, 1956). We believe this theory suitable to explain the current findings which show the increasing effectiveness of a given amount of light when given in numerous small doses.

The formulation of general theories on the basis of published evidence is seriously hampered by non-uniformity in experimental material, procedures, and terminology. On the basis of Farner's theory and present findings, one may attempt to interpret light response by means of three independent main effects and their interactions, namely:

1. Total daily amount of light exposure
2. Light intensity
3. Frequency of light intervals.

Additional assumptions are needed in order to explain refractoriness and perhaps seasonal changes in reproduction of birds, but the present experiments do not permit any new interpretation of their role.

Summary

The present experiments were designed to determine the effects of:

a. Total daily amount of light
b. Intensity of light
c. Frequency of light intervals

on the growth and development of Leghorn chickens.

a. *Total daily amount of light exposures:* The first test dealt with the effect of supplementing natural light with continuous light. Continuous light improved body weight of all birds and testes size of males at 7 weeks, but impaired feather development. Continuous lighting delayed sexual maturity of pullets, and growth in both sexes was retarded until they reached 20 weeks of age.

In the second experiment under suboptimal light intensities, light exposure has no effect on body size after 12 weeks of age. Rate of sexual development was increased by larger daily exposures to light. These effects were more pronounced when treatments were applied to pullets over 90 days old than during earlier stages of development.

b. *Intensity of light:* Three light intensities were applied to growing birds: 0.0–0.4 foot-candles, 0.4–6.6 foot-candles, and 0.5–30.0 foot-candles. Growth was not affected by lower light intensities, but sexual maturity was delayed.

c. *Frequency of light intervals:* Body weight was unaffected by lighting frequency. Sexual maturity, however, was significantly advanced when suboptimal light exposure and light intensities were applied in frequent but small doses. Thus, it was found that 12 periods of 7.5 minutes of dim light per day produced a rate of sexual development almost equal to the rate with 14 hours per day of normal lighting. These results are taken as further proof that the after-effects of light on the reproductive mechanisms of chickens are considerable

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